

has been no special hardship due to scarcity. The following table gives the depth of snow on the ground at Summit, Placer County, Cal.:

Years.	Dec. 1.	Dec. 15.	Dec. 31.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1907.....	0	47	87
1908.....	24	32	21
1909.....	2	24	45
1910.....	7	4	4
1911.....	1	2	56
1912.....	T.	14	19

SUNSHINE.

The following table gives the total hours of sunshine and percentages of the possible:

Stations.	Hours.	Percent- age of possible.	Stations.	Hours.	Percent- age of possible.
Eureka.....	75	26	Sacramento.....	215	73
Fresno.....	230	77	San Diego.....	268	86
Los Angeles.....	276	90	San Francisco.....	192	65
Mount Tamalpais.....	196	66	San Jose.....	225	75
Red Bluff.....	174	60	San Luis Obispo.....	258	85

There was more sunshine during the current December than during the same month last year.

NOTES ON THE RIVERS OF THE SACRAMENTO AND LOWER SAN JOAQUIN WATERSHEDS FOR DECEMBER, 1912.

By N. R. TAYLOR, Local Forecaster.

Sacramento watershed.—The rivers of this watershed were much below the stages usually maintained during December and were even lower than during the preceding month. In some of the reaches of the Sacramento River stages 1 foot lower than those of November were reported.

There was a marked deficiency in rainfall over all sections of the Sacramento Valley, especially in the lower portion, where the rainfall was the lightest on record for December. Rain, mostly light, was general from about the 10th to the 15th and during this period from 15 to 20 inches of snow accumulated in the high ranges of the Sierra Nevada, but the prevailing low temperatures retarded the melting of snow and likewise reduced the run-off of all mountain streams. The greatest rise in any stream during the month was 4.6 feet at Red Bluff during the 24 hours ending at 7 a. m. of the 15th, but this flattened out as it moved downstream and resulted only in a slight swell in the lower reaches of the river.

There was a scarcity of water for mining purposes during the entire month.

Lower San Joaquin watershed.—The rivers of this watershed remained at extreme low stages during the month. The San Joaquin River itself was, with one exception, the lowest of which there is a record for December. Precipitation throughout the drainage basin was light and there was no appreciable increase in the run-off of any of the mountain streams as a result of melting snow.

NOTES ON THE RIVERS OF THE UPPER SAN JOAQUIN WATERSHED.

By W. E. BONNETT, Local Forecaster.

During the month of December there was but one general rain in the watershed of the upper San Joaquin and it was not in sufficient amount to cause any rise in the streams. The stages were very low and uniform through-

out the month with ranges at the various stations of but one or two tenths of a foot.

In many ways the weather of December was like that of the same month last year but the abnormalities were more pronounced. Fewer days with fog were recorded than ever before, the percentage of humidity was the lowest and the number of clear days the greatest of record. These conditions were brought about by the scarcity of rain and resulted in a great daily range of temperature, the day temperatures being somewhat higher than normal and the night temperatures very much lower. There was an unusual succession of heavy to killing frosts with the temperature at the ground 25° or below on 15 days of the month.

OCEAN TEMPERATURES ON CALIFORNIA COAST.

By GEORGE F. McEWEN.

[Summary by author of a paper prepared for the University of California, Department of Zoology.]

The presence along the west coast of North America of a belt of cold surface water having at any point a much lower temperature than is normal for the corresponding latitude has long been known. And several papers have been written in which a diversity of merely qualitative explanations of this interesting and perplexing phenomenon have been given. The present paper is an attempt to explain quantitatively the temperature distribution by means of a new theory of oceanic circulation, developed by V. W. Ekman, of Kristiana.

The contents of this paper fall under the following nine heads:

I. A brief summary of some important and generally accepted facts concerning oceanic temperatures and circulation.

II. A brief review of the theories that have been proposed to account for the cold-water belt along the west coast of North America.

III. An abstract of the most important part of Ekman's theory of oceanic circulation needed in attacking the above-mentioned problems.

IV. Some general qualitative applications of his theory to a variety of temperature problems.

V. The formulation of a temperature problem in such a way that a quantitative estimate of the mean monthly surface-water temperature for any given place can be made by means of the physical theory of heat and circulation.

VI. The solution of the above problem for four very different regions along the Pacific coast, and a comparison of the observed and calculated values.

VII. A discussion of the results, and additional test of the theory using the observations made by the Marine Biological Association of San Diego in a much more limited area.

VIII. Some remarks on the influence of ocean temperatures on the coast climate of California.

IX. Summary and conclusion.

IX. SUMMARY AND CONCLUSIONS.

Numerous observations extending over a long period have established the presence of abnormally cold surface water contiguous to the west coast of North America,

¹ McEwen, Geo. F., The Distribution of Ocean Temperatures Along the West Coast of North America Deduced from Ekman's Theory of the Upwelling of Cold Water from the Adjacent Ocean Depths. Internationale Revue der gesamten Hydrobiologie und Hydrographie, 1912, Band V, Heft 2 und 3, pp. 243-286, 21 text figures, 4 tables.

but a diversity of conflicting theories have been proposed by various writers to account for the phenomenon.

The conclusions reached by different investigators may be summarized as follows:

1. A cold Arctic current flows south along the coast from the polar regions.

2. The Japan current, because of its passage through high latitudes, becomes cooled, and as it flows south along the coast of the United States appears as a cold stream because its temperature corresponds to the normal value prevailing in higher latitudes.

3. The accumulation of water in the south polar region causes an excess of pressure which drives the cold bottom water northward with an increasing velocity owing to the diminishing distance across the Pacific, till when it reaches the latitude of Sitka, Alaska, owing to the deflecting force due to the earth's rotation, it is driven up the continental slope and flows south as a cold current, since it has no other outlet.

4. The coldest water is located about 800 miles south of Sitka in the summer time, and areas of alternately warm and cold water are distributed in an irregular manner all along the coast. But from each of the previous theories, owing to the continual increase in the heating effect of the sun toward the south, a continuous rise in temperature would accompany a decrease of latitude. Therefore the low temperature must result from an upwelling of cold bottom water from the adjacent ocean depths. A general eastward drift of the ocean water extending to the bottom is assumed to result from the continued action of the winds; consequently the cold bottom water is driven up the continental slope, most of it reaching the surface at Cape Mendocino (the coldest region). The irregularities in temperature distribution are due to the effects of submarine valleys and differences in the slope of the ocean bottom.

The above theories were based on hypothetical causes, which in some cases were not verified except by the general qualitative agreement of the deductions with the particular observations considered, and the theory of oceanic circulation proposed in 1878 by Zöppritz was widely used. No attempt was made to explain the seasonal fluctuation.

Before going on with the conclusions regarding the Pacific coast region it will be necessary to consider general theories of oceanic circulation. A recent one due to Ekman differs from that of Zöppritz in that no assumption as to regular flow in plane layers is used as a basis, but a virtual value of the coefficient of viscosity, allowing for the actual turbulent motion of the water is used, and the deflecting force due to the earth's rotation is also introduced. Many results of Zöppritz's theory are inconsistent with observations, while those of Ekman's theory are in harmony with experience. Most of the results of the two theories are entirely different.

From Ekman's theory it follows that there must be an upwelling of the cold bottom water along most of the coast of North America owing to the action of the observed winds, and in the present paper, assuming the low temperature to be due entirely to cold bottom water

upwelling and mixing with the surface water, a theoretical formula was derived by which the abnormally low temperatures of any region could be computed for each month of the year. A very satisfactory agreement with observations was obtained, though the temperature reduction below the normal varied from 0° to 8° C.

The following table showing the data used and the results obtained, for a belt of water extending west from San Francisco, indicates the agreement between the theoretical and observed temperatures. The formula derived for this region is $T = (1 - 0.030V_w)t_2 + 0.030V_w t_1$, in which

T is the surface temperature of the in-shore water,

t_2 is the normal surface temperature for the latitude,

t_1 equals 8° , the mean temperature of the upwelling water (centigrade), and

V_w is the component of the average wind velocity in miles per hour parallel to the coast line over an area whose center is about 400 kilometers from the coast. All of the variable quantities correspond to the same month.

Month.	V_w .	t_2 .	Calculated T.	Observed T.	Differ- ences.
		$^{\circ}$ C.	$^{\circ}$ C.	$^{\circ}$ C.	$^{\circ}$ C.
1	7.70	14.20	12.80	12.50	0.30
2	6.87	13.80	12.60	11.60	1.00
3	9.25	12.60	11.30	11.50	-0.20
4	11.40	12.00	10.60	11.30	-0.70
5	12.50	14.50	12.10	11.30	0.80
6	14.40	15.20	12.10	13.80	-1.70
7	17.50	20.00	13.70	13.50	0.20
8	18.60	19.90	13.25	13.00	0.25
9	17.60	19.90	13.60	13.80	-0.20
10	13.60	18.10	14.30	14.60	-0.30
11	8.80	16.60	14.30	13.90	0.50
12	6.65	15.20	13.80	13.40	0.40

In general the theory shows that the area affected and the magnitude of the temperature reduction and its distribution vary with the depth of the water, the slope of the bottom, the velocity of the winds, the portion of the surface over which they extend, and their steadiness.

To give an idea of the peculiarities of temperature distribution that have been accounted for by means of these principles the following results of observation are enumerated.

The cooling effect of the upwelling water extends to a distance of 600 kilometers from the coast off Cape Mendocino, latitude 40° , and increases to a distance of 2,100 kilometers from the shore off San Diego, latitude $32^{\circ} 45'$.

The temperature reduction in the summer is a minimum off San Diego and a maximum off Cape Mendocino where the coldest surface water is found.

Temperatures as low as 14° C. in August have been found in certain limited areas near the coast south of latitude 35° , while the value 18° C. prevailed in the surrounding water a few miles away, both north and south.

Considering the complexity of the phenomena, the agreement between the theory and the observations has been very satisfactory, and judging from the results already obtained it would be profitable to carry on a more detailed and quantitative investigation following the lines suggested in the present paper.